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H2H HBCD HBCG

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US 5880575 A
US 5557189 A
US 5773959 A

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ONLINE: EPODOC, JAPIO, WPI

(54) Abstract Title

Battery charging system

(57) A battery charging system is provided which monitors and controls the charging of a battery having a number of series connected battery cells C_1-C_n. The system comprises a central battery monitoring system 3 which monitors the battery as a whole and a number of cell monitoring devices C_{M1}-C_{Mn} which monitor one or more of the battery cells. In operation the cell monitoring devices transmit status information on the battery cells which they monitor and ambient temperature 5 and the central battery monitoring system analyses this status information and transmits control signals to the cell monitoring devices so that an appropriate load (61,63 fig.5) is connected across the terminals of the battery cell. By controllably connecting loads across the terminals in this way, the charging of the individual cells in the battery can be controlled.

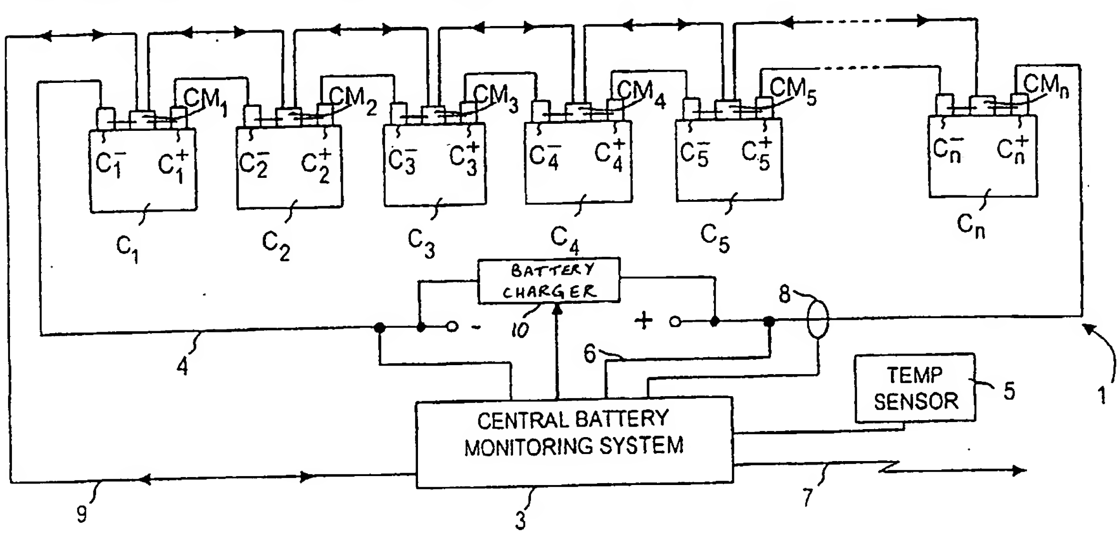

FIG.1

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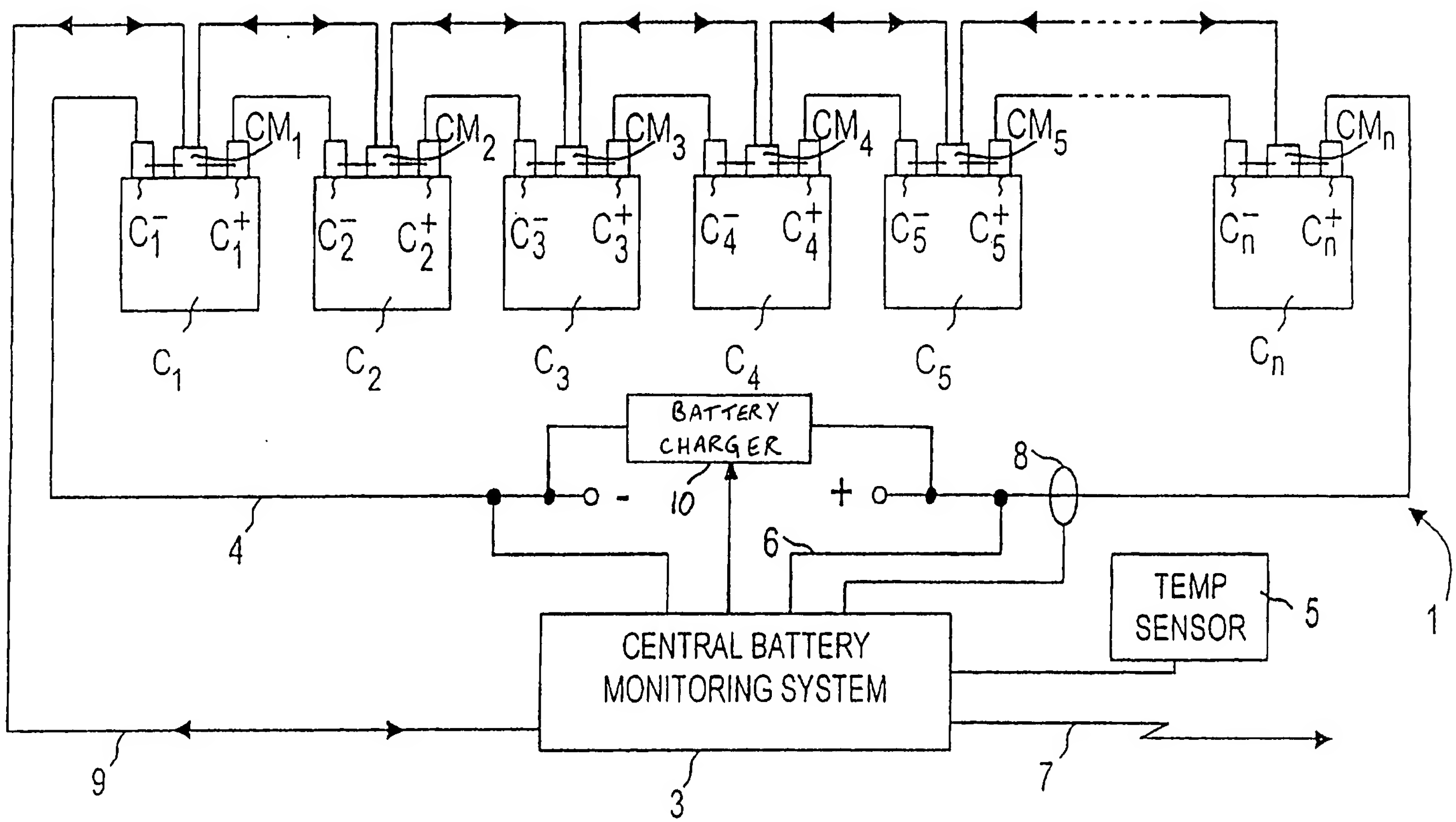

CM1
CM2
CM3
CM4
CM5
CMn
C1- C1+
C2- C2+
C3- C3+
C4- C4+
C5- C5+
Cn- Cn+
C1
C2
C3
C4
C5
Cn
BATTERY CHARGER
10
- +
8
4
6
1
TEMP SENSOR
5
CENTRAL BATTERY MONITORING SYSTEM
9
3
7

FIG.1

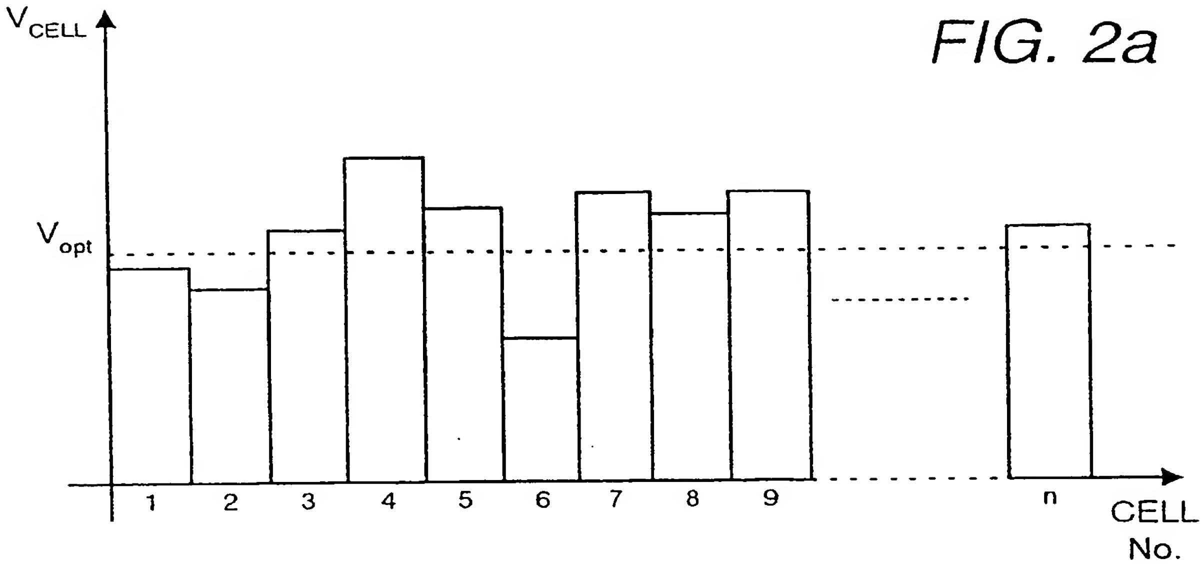


FIG. 2a

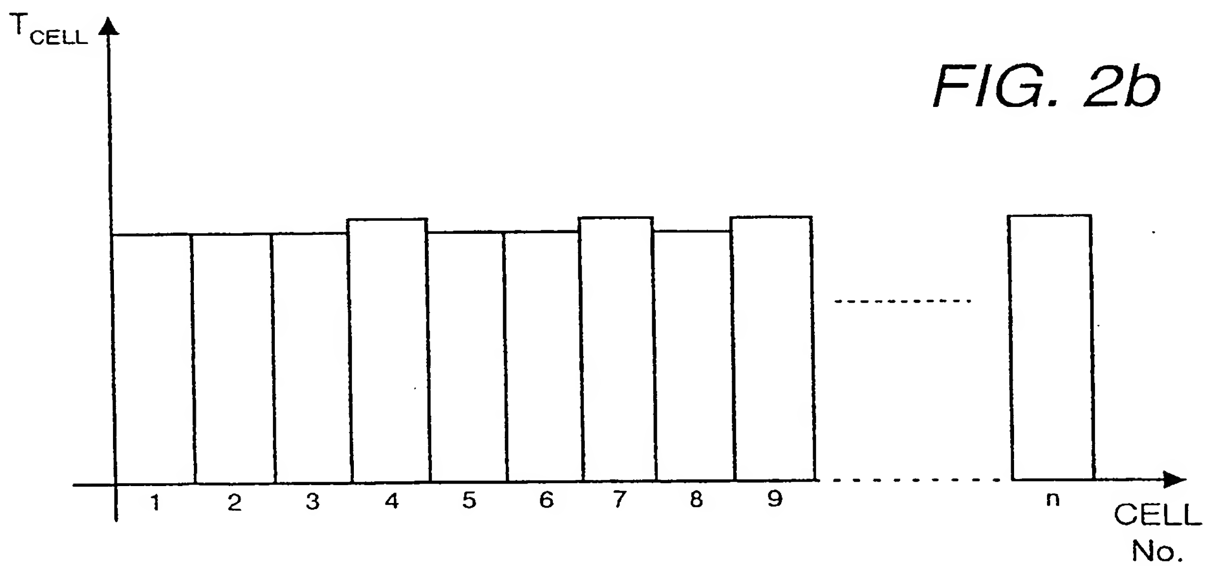
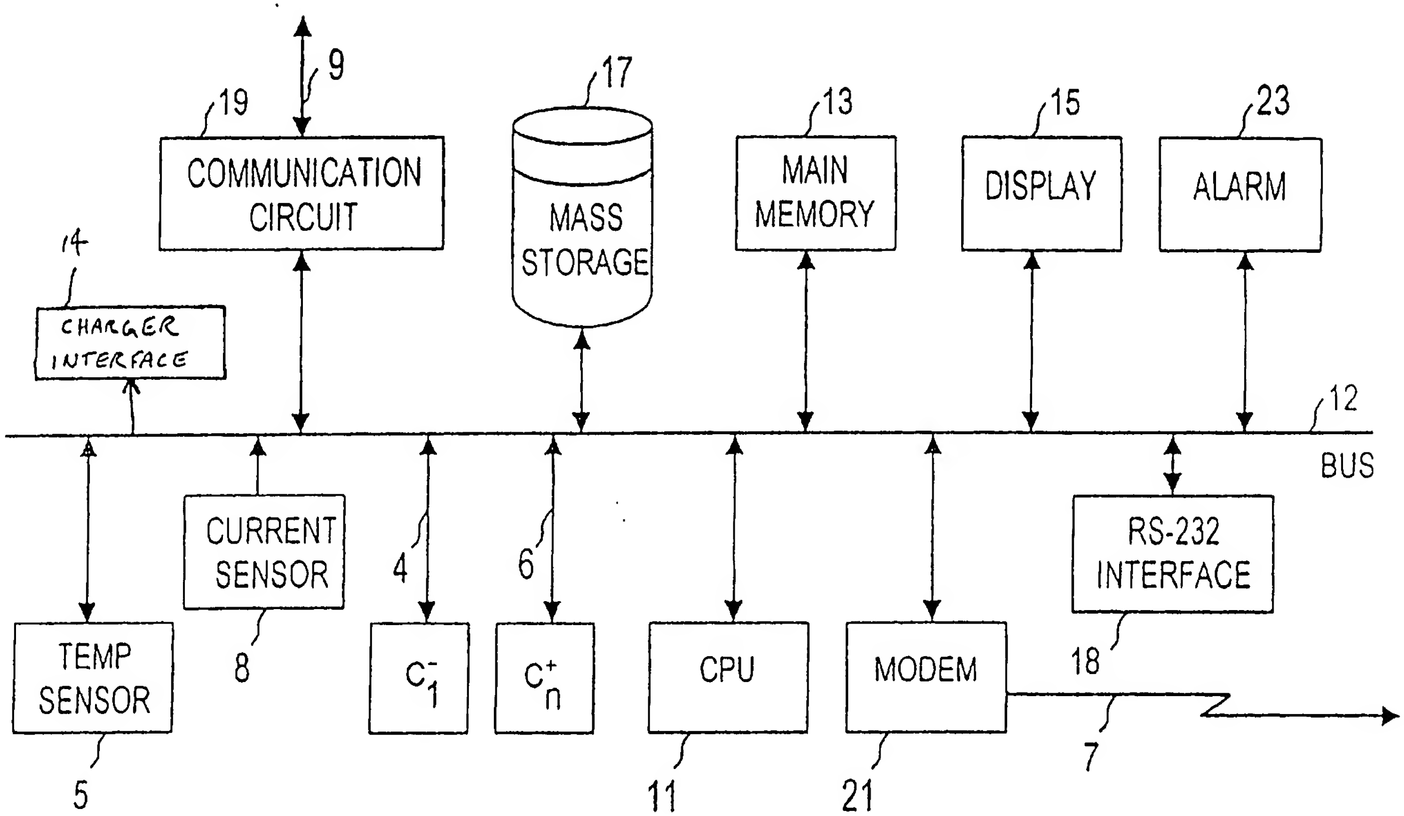
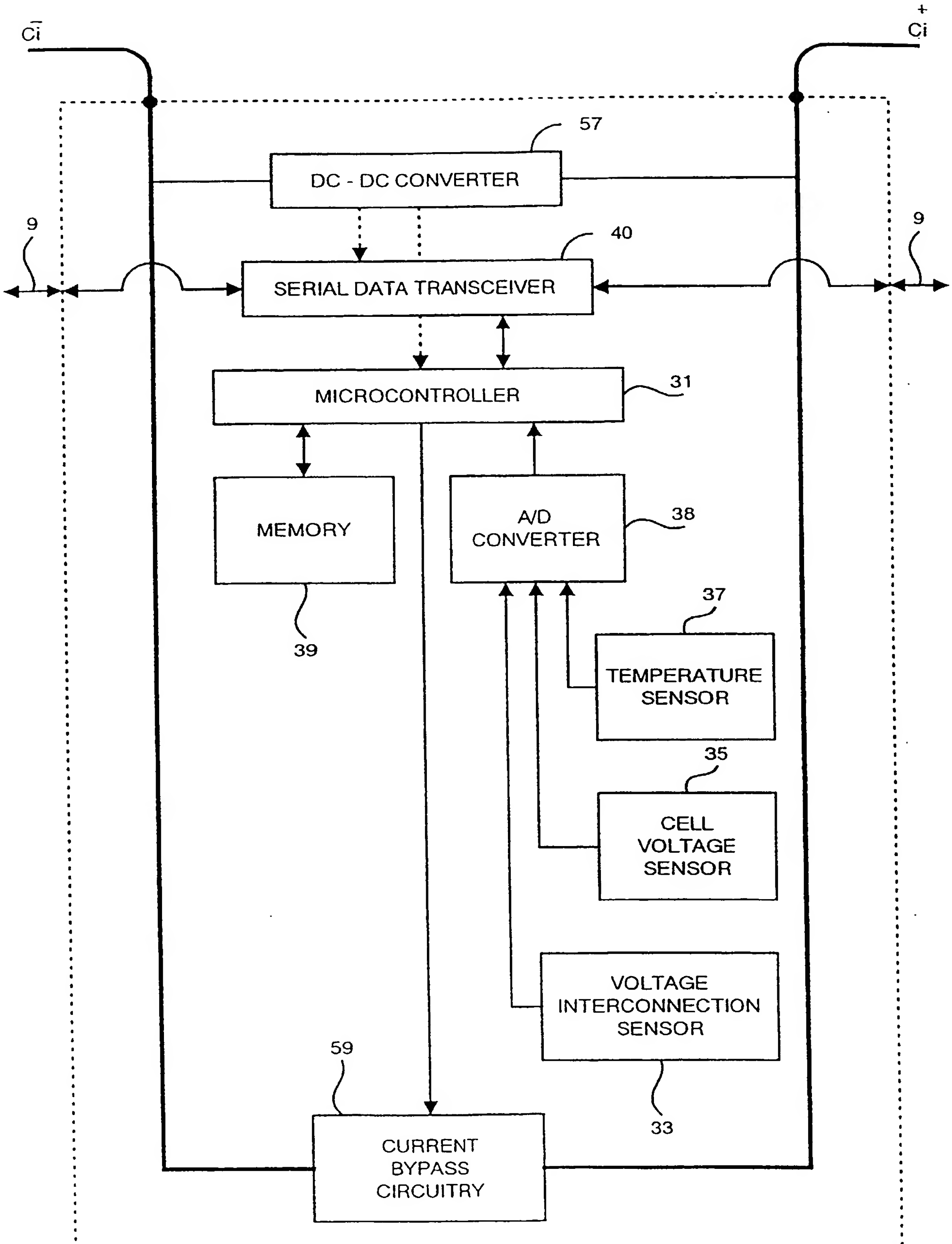


FIG. 2b



9
19
COMMUNICATION CIRCUIT
17
MASS STORAGE
13
MAIN MEMORY
15
DISPLAY
23
ALARM
14
CHARGER INTERFACE
12
BUS
CURRENT SENSOR
8
TEMP SENSOR
5
4
C_1^-
6
C_n^+
CPU
11
MODEM
21
RS-232 INTERFACE
18
7

FIG. 3



Ci
+
Ci
57
DC - DC CONVERTER
9
9
40
SERIAL DATA TRANSCEIVER
MICROCONTROLLER
31
MEMORY
A/D CONVERTER
38
39
37
TEMPERATURE SENSOR
35
CELL VOLTAGE SENSOR
VOLTAGE INTERCONNECTION SENSOR
59
33
CURRENT BYPASS CIRCUITRY

FIG. 4

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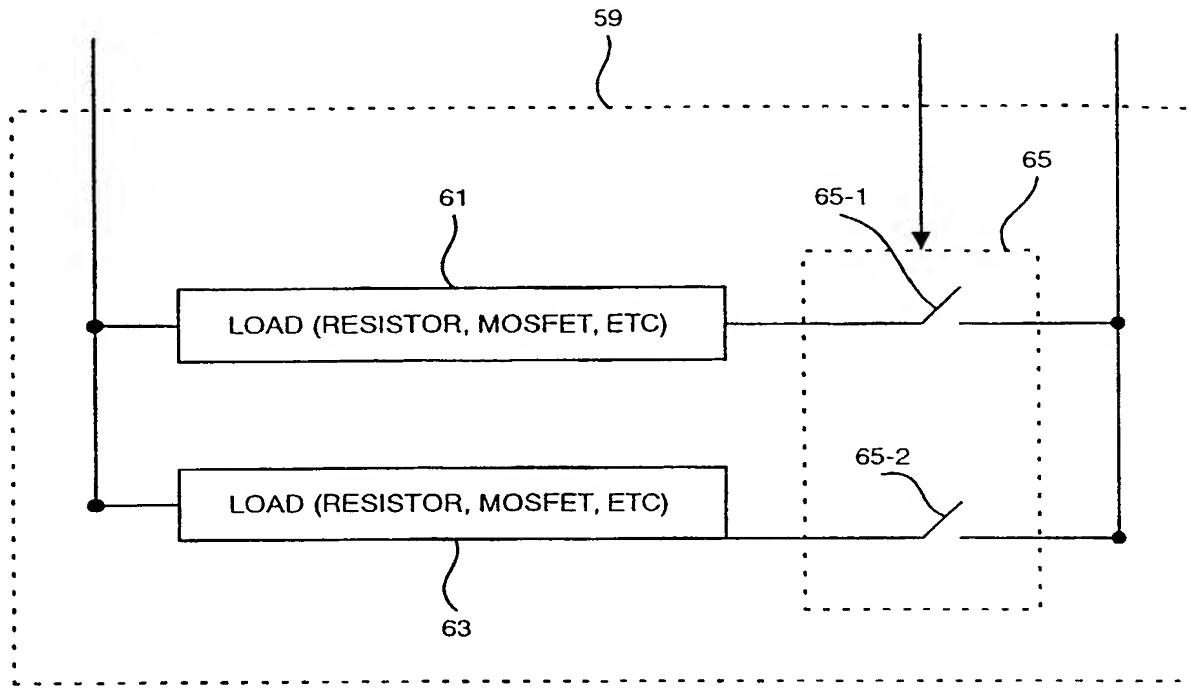
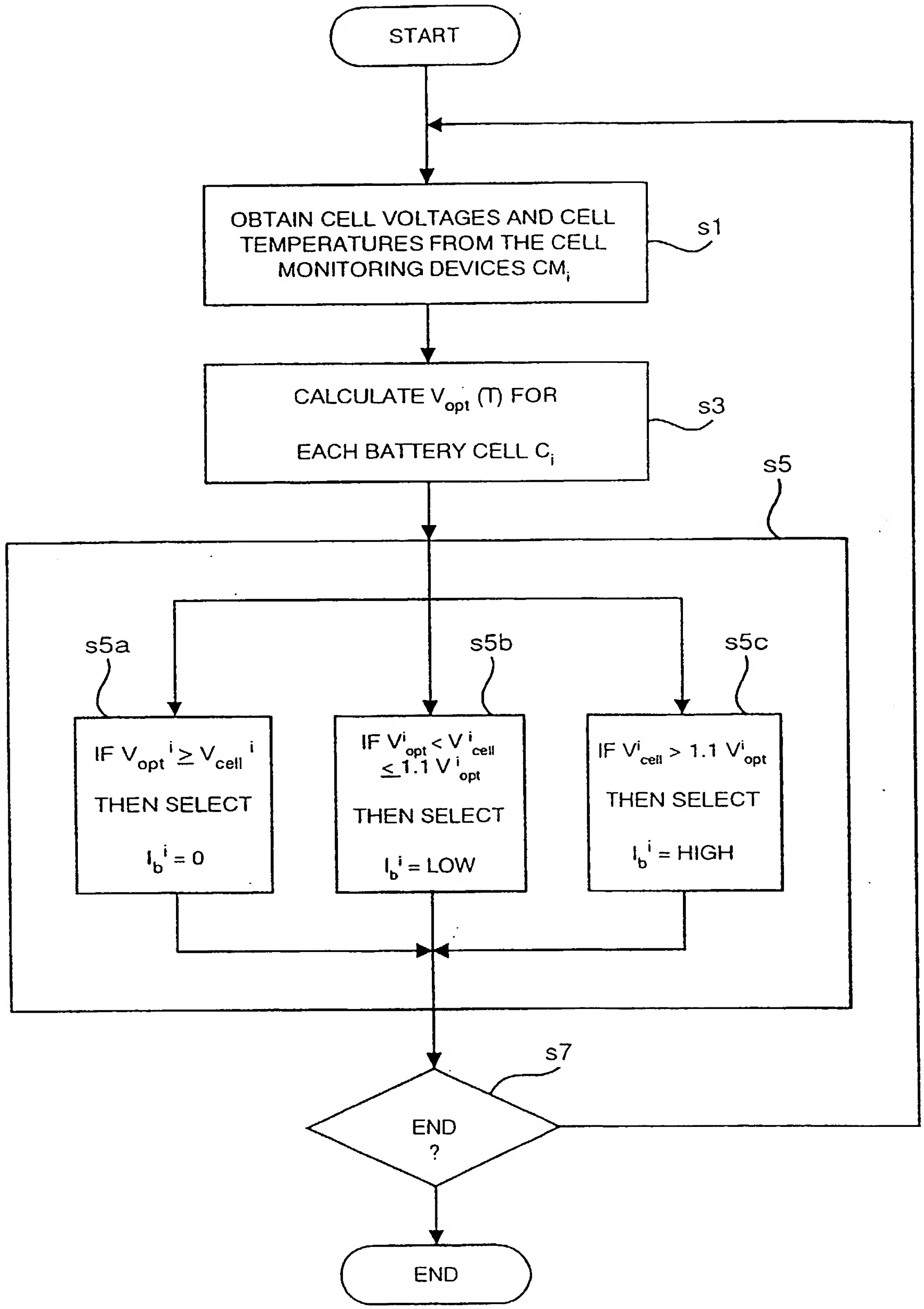

59
61
65
65-1
LOAD (RESISTOR, MOSFET, ETC)
65-2
LOAD (RESISTOR, MOSFET, ETC)
63

FIG. 5



START
OBTAIN CELL VOLTAGES AND CELL TEMPERATURES FROM THE CELL MONITORING DEVICES CM_i
s1
CALCULATE V_{opt} (T) FOR EACH BATTERY CELL C_i
s3
s5
s5a
s5b
s5c
IF $V_{opt}^{i} \geq V_{cell}^{i}$ THEN SELECT $I_b^i = 0$
IF $V^i_{opt} < V^i_{cell} \leq 1.1\, V^i_{opt}$ THEN SELECT I_b^i = LOW
IF $V^i_{cell} > 1.1\, V^i_{opt}$ THEN SELECT I_b^i = HIGH
s7
END ?
END

FIG. 6

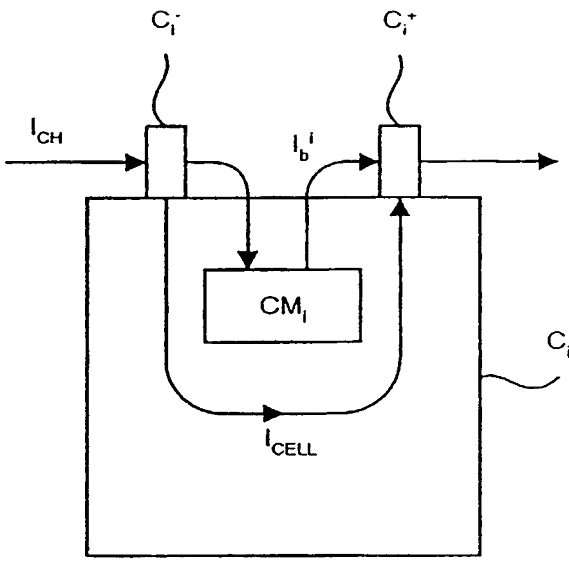


FIG. 7a

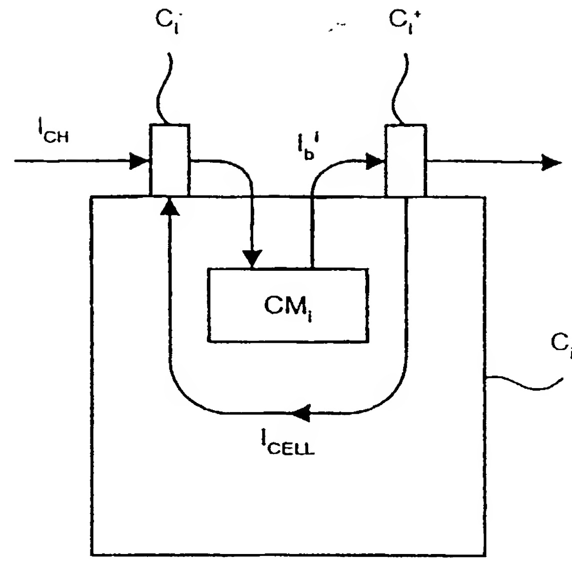


FIG. 7b

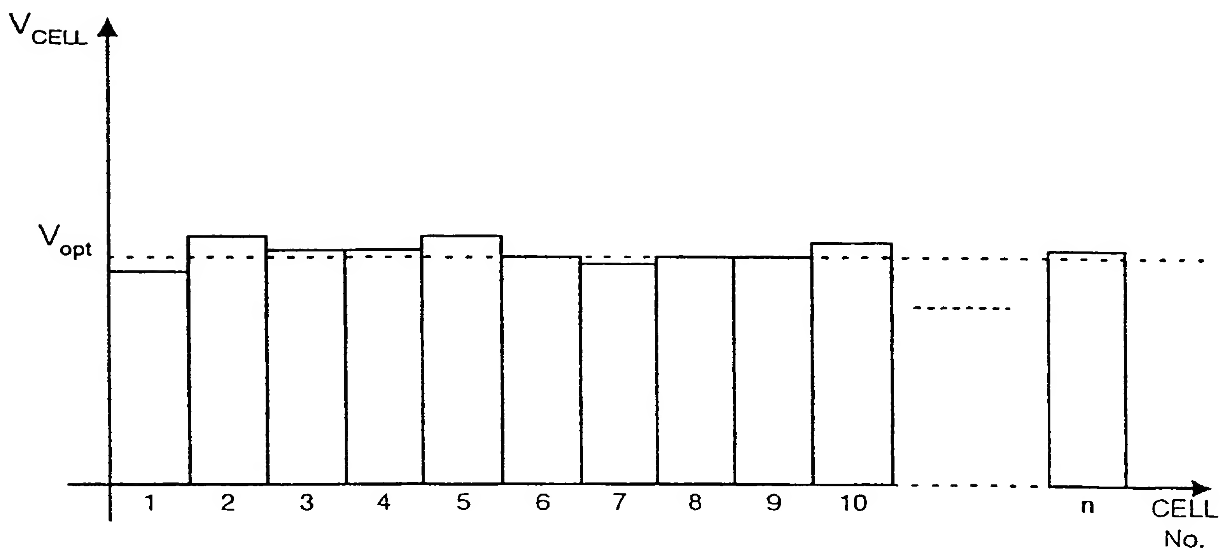


FIG. 8

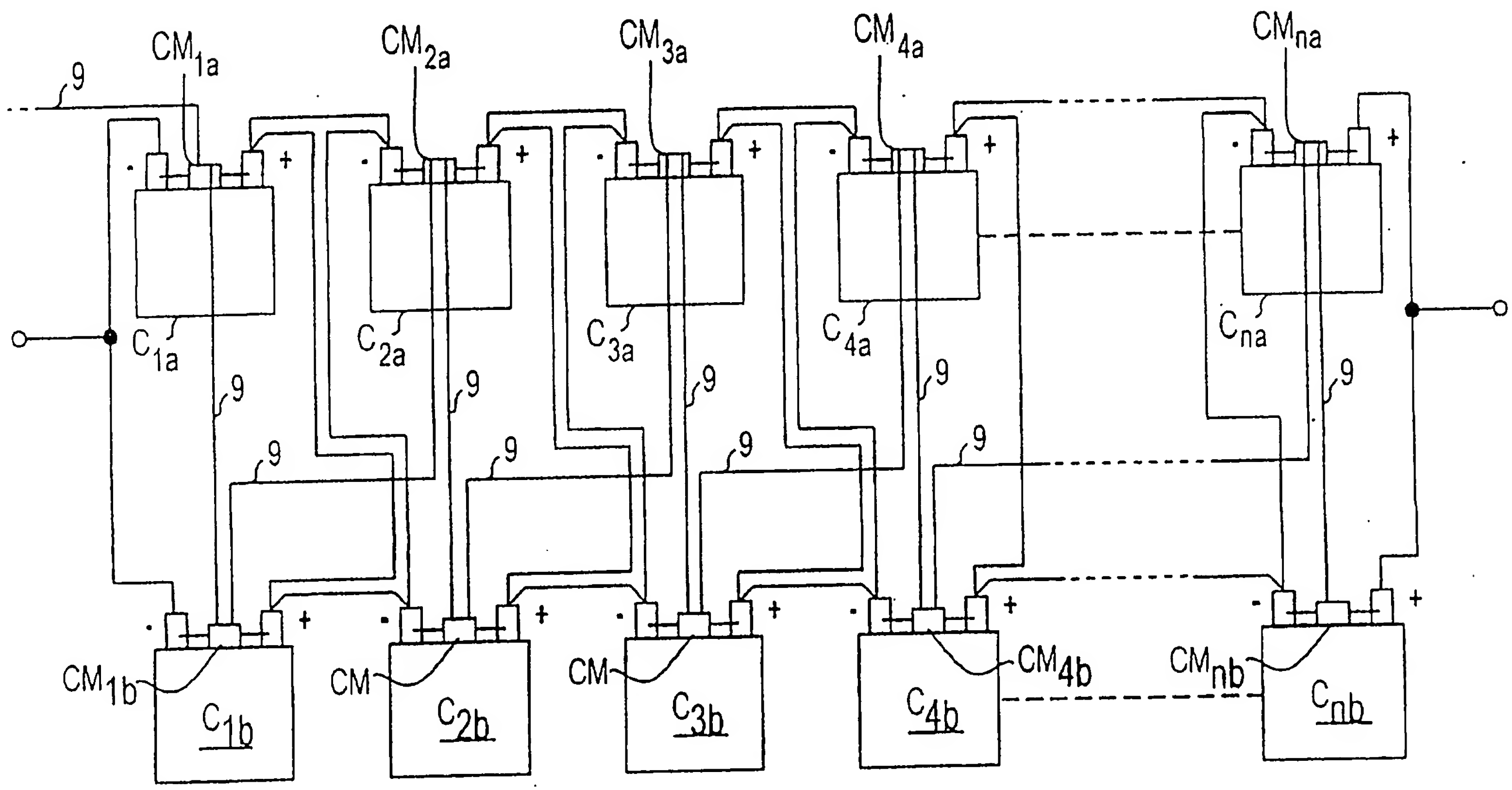

9
CM1a
CM2a
CM3a
CM4a
CMna
+
-
C1a
C2a
C3a
C4a
Cna
CM1b
CM
CM
CM4b
CMnb
C1b
C2b
C3b
C4b
Cnb

FIG. 9

BATTERY CHARGING SYSTEM

The present invention relates to a method and apparatus for charging cells of an industrial battery.

Industrial batteries comprise a number of rechargeable battery cells which can be electrically connected in various series and series-parallel combinations to provide a rechargeable battery having a desired output voltage. To recharge the battery, a current is passed through the cells in the opposite direction of current flow when the cells are working. There are many different types of battery cells available, but those most commonly used in industrial applications are lead acid battery cells, each of which provides 2 volts, and nickel-cadmium (Nicad) battery cells, each of which provides 1.2 volts.

The batteries are usually used as a back-up power supply for important systems in large industrial plants, such as off-shore oil rigs, power stations and the like. Since the batteries are provided as back-up in the event of a

fault with the main generators, they must be constantly monitored and maintained so that they can provide power to the important systems for a preset minimum amount of time.

One of the problems with industrial batteries is that the battery cells in the string are never equally charged and the older the string is the more unequally charged the cells are. Some cells are overcharged while other cells are undercharged. This can reduce the life of the battery as a whole since the overcharged cells die sooner.

The present invention aims to provide a system which will alleviate this problem.

According to one aspect, the present invention provides a rechargeable battery system comprising a battery which includes a number of battery cells; a battery charger for charging the battery; a sensor for sensing a measure of the existing charge of at least one of the battery cells; means for comparing the measure of the existing charge

with a threshold value; and means for selectively connecting a load across at least one battery cell in dependence upon the output of said comparing means. By monitoring the existing charge on some of the battery cells, and by controllably connecting a load to those battery cells if appropriate, the battery charging system can intelligently charge the battery as a whole. In particular, even though a constant charging battery voltage is applied to the battery, the charging current experienced by each of the cells will depend upon whether or not a load is connected across the terminals of the cell. If a load is connected then some of the charging current will be diverted away from the cell, thereby reducing the rate at which that cell is charged relative to the other cells. In a preferred embodiment, cells which are severally overcharged (e.g. more than 10% higher than the optimum charging voltage) are actually discharged during the battery charging operation. This is preferably achieved by connecting a low valued load across the terminals of the battery cell so that all of the charging current passes through the load together with some current drawn from the cell. The appropriate

value of the load resistor is heavily dependent on the battery size (Amps.hour) and technology. For example, for a lead acid cell of 2 volts and 100 Amps.hour, an adequate load resistor is 0.2 Ohms, which allows for a load current of approximately 10 Amps.

According to another aspect, the present invention provides a battery cell monitoring device comprising: means for receiving a measure of the existing charge of a battery cell to be monitored; means for communicating this measure to remote monitoring system; means for receiving communications from the remote monitoring system; a load connectable across power terminals of the battery cell; and means for selectively connecting the load to the battery cell in dependence upon a communication received from the remote monitoring system.

According to another aspect, the present invention provides a battery cell monitoring device comprising: means for receiving a measure of an existing charge of the battery cell to be monitored; means for comparing the measure with a threshold value and for outputting a

comparison result; a load connectable across the battery cell; and means for selectively connecting the load across the battery cell in dependence upon the comparison result.

The present invention will now be described by way of example only with reference to the accompanying drawings, in which:

Figure 1 schematically shows a battery comprising a number of battery cells connected in series, a central battery monitoring system for monitoring the condition of the battery as a whole, individual cell monitoring devices for monitoring the cells of the battery and a battery charger for charging the battery cells;

Figure 2a is a plot showing the distribution of charge between the battery cells shown in Figure 1;

Figure 2b is a temperature profile illustrating the variation of temperature between the cells shown in Figure 1;

Figure 3 is a schematic diagram showing more detail of the central battery monitoring system shown in Figure 1;

Figure 4 is a schematic diagram of one of the cell monitoring devices shown in Figure 1;

Figure 5 is a schematic diagram of bypass circuitry which forms part of the cell monitoring device shown in Figure 4;

Figure 6 is a flow-chart illustrating some of the processing steps performed by the central battery monitoring system shown in Figure 1, prior to and during a charging operation;

Figure 7a illustrates a charging operation for one of the battery cells shown in Figure 1 when the voltage of that cell is slightly greater than the optimum charging voltage for that cell;

Figure 7b illustrates a charging operation for one of the battery cells shown in Figure 1 when the voltage of that

cell is much greater than the optimum charging voltage for that cell;

Figure 8 is a plot illustrating the distribution of charge between the battery cells shown in Figure 1 after the charging operation has been carried out; and

Figure 9 is a schematic representation of an industrial battery in which the cells of the battery are connected in a series-parallel configuration.

A first embodiment of the present invention will now be described with reference to Figures 1 to 8. Figure 1 schematically shows an industrial battery, generally indicated by reference numeral 1, comprising a number of lead acid battery cells C_1, C_2, C_3 ... C_n connected so that the negative terminal C_i^- of cell C_i is connected to the positive terminal C_{i-1}^+ of preceding cell C_{i-1} and the positive terminal C_i^+ of cell C_i is connected to the negative terminal C_{i+1}^- of the succeeding cell C_{i+1}, whereby the negative terminal C_1^- of the first cell C_1 is the negative terminal of the battery and the positive

terminal C_n^+ of the last cell C_n is the positive terminal of the battery. Since the battery cells are lead acid, they each provide approximately 2 volts and the voltage of the battery as a whole will be approximately 2n volts. For industrial applications a voltage of 120 volts is often required. Therefore, 60 series connected lead acid or 100 series connected Nicad battery cells would be required. Sometimes, each cell in the series connection is connected in parallel with one or more similar cells, so as to provide redundancy, so that the battery will not fail if a single cell fails.

Figure 1 also shows a central battery monitoring system 3 which is powered by the battery 1 via connectors 4 and 6, which connect the central battery monitoring system 3 to the negative terminal C_1^- and the positive terminal C_n^+ of the battery 1, respectively. The battery monitoring system 3 monitors the status of the industrial battery 1 as a whole, based on charging and discharging characteristics of the battery (determined by monitoring the battery voltage from connectors 4 and 6 and the current being drawn from or supplied to the battery 1,

which is sensed by current sensor 8, whilst the battery is being charged and subsequently discharged), the ambient temperature (input from temperature sensor 5) and on information relating to the efficiency characteristics of the battery cells (provided by the battery cell manufacturer). The monitoring results can be stored in the central battery monitoring system 3 or they can be transmitted to a remote user (not shown) via the telephone line 7.

Each of the battery cells C_i, shown in Figure 1, also has a battery cell monitoring device CM_i mounted on top of the cell between its positive and negative terminals C_i^+ and C_i^- respectively, which monitors the status of the cell C_i. Each cell monitoring device CM_i is powered by the cell C_i which it monitors and communicates with the central battery monitoring system 3 via a communication link 9. The communication link 9 connects the cell monitoring devices CM_i in series in a daisy chain configuration to the central battery monitoring system 3, so that communications from the central battery monitoring system 3 to the cell monitoring devices CM_i

pass along the link 9 from left to right and communications from the cell monitoring devices CM_i to the central battery monitoring system 3 pass along the link 9 from right to left. Each cell monitoring device CM_i has its own cell identification or address, which, in this embodiment, is set in advance using DIP-switches mounted in the device. This allows communications from the central battery monitoring system 3 to be directed to a specific cell monitoring device and allows the central battery monitoring system 3 to be able to identify the source of received communications.

In this embodiment, the central battery monitoring system 3 is also used to control a battery charger 10 which is connected across the ends of the battery via connectors 4 and 6. In this embodiment, the central battery monitoring system 3 monitors the charging current, the remaining battery capacity, the ambient temperature etc and controls the operation of the battery charger 10 so that the battery is charged in accordance with the specific charging procedures recommended by the battery manufacturer for the battery 1.

The battery monitoring system shown in Figure 1 operates in three modes. In the first mode, the central battery monitoring system 3 monitors the condition of the industrial battery 1 as a whole and polls each of the cell monitoring devices CM_i in turn. During this mode, each of the cell monitoring devices CM_i listens to communications from the central battery monitoring system 3 on the communication link 9 and responds when it identifies a communication directed to it. When polled, each cell monitoring device CM_i performs a number of tests on the corresponding battery cell C_i and returns the results of the tests back to the central battery monitoring system 3 via the communication link 9.

In the second mode of operation, the central battery monitoring system 3 listens for communications on the communication link 9 from the cell monitoring devices CM_i indicating that there is a faulty condition with one of the battery cells C_i. In this second mode of operation, each cell monitoring device CM_i continuously monitors the corresponding battery cell C_i and, upon detection of a faulty condition, checks that the communication link 9 is

free and then sends an appropriate message back to the central battery monitoring system 3 via the communication link 9.

In the third mode of operation, the central battery monitoring system 3 causes the battery charger 10 to recharge the battery 1 by applying a fixed charging voltage across the terminals of the battery 1 and controls each of the cell monitoring devices in an intelligent manner so that the individual battery cells are charged in accordance with their existing charge. In particular, in a string of battery cells, the battery cells are never equally charged and the older the string is the more unequally charged the cells are. Some cells are overcharged whereas other cells are undercharged.

Figure 2a is a plot which shows a typical distribution of charge (as measured by the cell voltages) between the battery cells in a string. As shown, some cells are slightly overcharged relative to an optimal charging voltage (V_{OPT}) such as battery cell C_3, others are severely overcharged such as battery cell C_4 and others

are undercharged such as battery cell C_6. In this embodiment, the central battery monitoring system 3 transmits appropriate control messages to the individual cell monitoring devices CM_i so that during the charging operation, cells that are severely overcharged do not get charged further (and are in fact discharged) and so that cells that are slightly overcharged are charged to a lesser extent than the other cells.

An additional complication arises since the optimal charging cell voltage which should be used is heavily dependent upon the cell's temperature. Figure 2b is a plot which shows an example of how the cell temperature varies along the string of battery cells in the battery 1. As shown, the battery cells are not all at the same temperature. Therefore, in this embodiment, the central battery monitoring system 3 also monitors the temperature of the individual cells so that during the charging operation, it can instruct the cell monitoring devices CM_i so that they are charged with an appropriate charging voltage.

Figure 3 is a schematic diagram of the central battery monitoring system 3 shown in Figure 1. As shown, the central battery monitoring system 3 comprises a CPU 11 for controlling the operation of the central battery monitoring system 3. The CPU 11 is connected, via data bus 12, to a main memory 13 where data from the input sensors is stored and where test programs are executed, to a charger interface 14 for interfacing with the battery charger 10, to a display 15 which displays the battery's current status and to a mass storage unit 17 for storing the sensor data and the results of the battery tests. The mass storage unit 17 can be fixed within the central battery monitoring system 3, but is preferably a floppy disk or a PCMIA memory card which can be withdrawn and input into an operator's personal computer for analysis. An operator can also retrieve the stored data and results and control the set up and initialisation of the central battery monitoring system 3 via the RS-232 serial interface 18. As mentioned above, instead of storing the test results in the mass storage unit 17, they can be transmitted via a modem 21 and telephone line 7 to a remote computer system (not

shown) for display and/or analysis. In this embodiment, if there is a fault with one of the battery cells C_i or if there is some other faulty condition, the CPU 11 triggers a local alarm 23 to alert a technician that there is a fault with the battery 1 or with one or more of the battery cells C_i. In this embodiment, the conditions which define a fault and their thresholds are user definable and are set in advance.

Figure 4 is a schematic diagram showing, in more detail, one of the cell monitoring devices CM_i shown in Figure 1. As shown, cell monitoring device CM_i comprises a microcontroller 31 for controlling the operation of the cell monitoring device CM_i and for analysing sensor data received from voltage interconnection sensor 33, cell voltage sensor 35 and temperature sensor 37 via analogue to digital converter 38. The microcontroller 31 operates in accordance with a program stored in memory 39 and control data received from the central battery monitoring system 3 via the communications link 9 and a serial data transceiver 40. Various types of data transceiver 40 can be used in the cell monitoring devices CM_i. For example,

transceivers that galvanically isolate each cell monitoring devices may be used. However, data transceivers such as those described in the applicant's earlier international applications WO98/32181 and WO00/05596 (the contents of which are incorporated herein by reference) are preferably used, for the reasons discussed in those earlier applications.

The voltage interconnection sensor 33 measures the voltage drop between the cell being monitored and its neighbouring cells, by measuring the potential difference between each terminal of the cell C_i and the respective terminal connections which connects cell C_i with its neighbouring cells. Ideally, there should be no voltage drop between each terminal and the corresponding terminal connection. However, due to chemical deposits accumulating at the cell terminals with time, or because of cell malfunction, a difference in potential between the cell terminals and the corresponding connectors sometimes exists, indicating that there is a fault, either with the battery cell C_i or with the interconnection with a neighbouring cell. The cell

voltage sensor 35 is provided for sensing the potential difference between the positive terminal C_i^+ and the negative terminal C_i^- of the cell C_i which it is monitoring. The temperature sensor 37 senses the cell temperature locally at the cell C_i. By monitoring the local temperature at each cell C_i, it is possible to identify quickly faulty cells or cells which are not operating efficiently.

The microcontroller 31 analyses the data input from the sensors and monitors for faulty conditions and reports to the central battery monitoring system 3 via the serial data transceiver 40 and the communication link 9. In order to power the cell monitoring device CM_i, the positive terminal C_i^+ and the negative terminal C_i^- of cell C_i are connected to the input of a DC to DC convertor 57, which generates, relative to the ground of cell C_i (which equals the voltage potential of the negative terminal C_i^- of cell C_i) a supply voltage ($V_{cc}{}^i$), which is used to power the microcontroller 31 and the other components in the device and which in this embodiment is C_i^- + 3 Volts.

As shown in Figure 4, the cell monitoring device CM_i also includes current bypass circuitry 59 which is connected between the positive terminal C_i^+ and the negative terminal C_i^- of cell C_i. As will be described in more detail below, the current bypass circuitry 59 is effectively a variable load which can be placed across the terminals of the battery cell C_i under control of the microcontroller 31. During the normal operating mode of the battery 1, the current bypass circuitry 59 in each cell monitoring devices CM_i is not operational. In other words, they are all open circuit. However, during the battery charging operation, the current bypass circuitry 59 in some of the cell monitoring devices is activated so that an appropriate load is placed across the terminals of those battery cells in order to control the amount of charging current that is applied to those cells.

Figure 5 shows in more detail the contents of the current bypass circuitry 59 used in this embodiment. As shown, in this embodiment the current bypass circuitry 59 includes two load resistors 61 and 63 which are connectable across the terminals of the battery cell C_i

through an electronic switch 65 (comprising switches 65-1 and 65-2) which is controlled by a control signal received from the microcontroller 31. In this embodiment load resistor 61 has a resistance of 2 Ohms and load resistor 63 has a resistance of 0.2 Ohms. In this embodiment, the current bypass circuitry 59 has three different configurations. In the first, the current bypass circuitry 59 is not connected across the terminals which is achieved by opening the switches 65-1 and 65-2. This is the configuration used during normal operation of the battery and when the cell is not overcharged. In the second configuration, the high valued resistor 61 is connected across the terminals of the battery cell C_i by closing the switch 65-1. As will be described in more detail below, this second configuration is used during a charging operation for cells which are slightly over charged. In the third configuration, the resistor 63 is connected across the terminals of the battery cell C_i by closing the switch 65-2. As will be described in more detail below, this third configuration is used during a charging operation for battery cells which are severally overcharged.

The way in which the battery 1 is charged in this embodiment will now be described in more detail. Figure 6 is a flow chart which illustrates the processing steps performed by the central battery monitoring system 3 before and during the charging operation. As shown, in Step S1, the central battering monitoring system 3 polls each of the cell monitoring devices CM_i to obtain various operating characteristics of the associated battery cells including the cell voltage and the cell temperature for each of the battery cells C_i. Based on these measurements and the charging characteristics recommended by the battery manufacturer, the central battery monitoring system 3 determines, in step S3, the optimal charging voltage ($V^i_{OPT}(T)$) for each cell C_i given the cell's temperature (T_i). The processing then proceeds to step S5 which comprises steps S5a, S5b and S5c, in which the central battery monitoring system 3 determines and then sends appropriate control signals to the cell monitoring devices CM_i in order to control the charging of the associated battery cells C_i. In particular, in step S5a, the central battery monitoring system 3 determines if the calculated optimum charging voltage

($V^i_{OPT}(T)$) for each cell (C_i) is equal to or greater than the cell voltage for that cell ($V_{CELL}{}^i$). If it is, then this means that the cell is either at the correct voltage or it is undercharged. Therefore, the current bypass circuitry 59 for this cell should not be activated. Consequently, the central battery monitoring system 3 sends an appropriate control signal via the communication link 9 to the associated cell monitoring device CM_i which causes the current bypass circuitry 59 to be switched to its open circuit configuration as discussed above.

At step S5b, the central battery monitoring system 3 determines, for each battery cell, if the cell voltage (V^i_{CELL}) of that cell lies between V^i_{OPT} and 1.1 V^i_{OPT}. If it is, then this embodiment considers that this cell is slightly overcharged and that therefore, the current bypass circuitry 59 for that cell should be activated in order to cause some of the charging current to bypass the cell. Consequently, the central battery monitoring system 3 sends an appropriate control signal, via the communication link 9, to the associated cell monitoring device CM_i which causes the resistor 61 to be connected

across the terminals of battery cell C_i. As illustrated in Figure 7a, this causes a portion (I_b^i) of the charging current I_{ch} to be diverted away from the cell through the cell monitoring device CM_i. As a result, battery cell C_i is "starved" of current relative to the other battery cells and this cell will therefore be charged at a lower rate than the other cells.

At step S5c, the central battery monitoring system 3 determines, for each battery cell, if the cell voltage (V^i_{CELL}) of that cell is greater than 1.1 V^i_{OPT}. If it is, then this embodiment considers that cell C_i is severely overcharged and that therefore, the current bypass circuitry 59 for that cell should be activated so that cell C_i discharges slightly. Consequently, the central battery monitoring system 3 sends an appropriate control signal, via the communication link 9, to the associated cell monitoring device CM_i for that cell which causes the lower valued resistor 63 of the current bypass circuitry 59 to be connected across the terminals of that battery cell C_i. The resulting current flow for this cell is illustrated in Figure 7b. As shown, all of the

charging current (I_{ch}) passes through the associated cell monitoring device CM_i together with extra current (I_{cell}) which is drawn from the battery cell itself. In this way, the overcharged cell C_i is actually discharged during the charging operation.

As those skilled in the art will appreciate, by discharging the overcharged cells, a new distribution of the charge within the battery 1 will automatically take place and the individual cell voltages and charges will be equalised. The voltage "shaved" from the overcharged cells will, in effect, be automatically redistributed to the undercharged cells.

After the central battery monitoring system has sent the appropriate control signals to each of the cell monitoring devices CM_i, the processing then proceeds to step S7 where the central battery monitoring system 3 determines whether or not the charging process is to end. If it is not, then the processing returns to step S1 where the above processing steps are carried out again. As those skilled in the art will appreciate, the charging

operation may be performed either under control of a supervisor or automatically until the central battery monitoring system determines that all of the battery cells have been charged to some predetermined charged level. Once this has happened, the processing ends.

Figure 8 is a plot which shows the resulting cell voltage distribution for the battery cells in the industrial battery 1, after the above charging operation has ended. As shown, the resulting charge is more evenly distributed across the battery cells.

MODIFICATIONS AND ALTERNATIVE EMBODIMENTS

A number of alternative embodiments will now be described, which operate in a similar manner to the first embodiment. Accordingly, the description of these alternative embodiments will be restricted to features which are different to those of the first embodiment.

In the above embodiment, each of the cell monitoring devices CM_i had current bypass circuitry having two resistances which can be connected across the terminals

of the corresponding battery cell C_i. As those skilled in the art will appreciate, the current bypass circuitry 59 may be made more complex or less complex depending on the application. For example, the current bypass circuitry may only have one resistor which is connectable across the terminals of the battery cell. In such an embodiment, either the resistor is connected across the terminals of the battery cell or it is not. Alternatively still, many different resistances may be provided within each current bypass circuit, each of which may be individually, or in combination with other resistances, connected across the terminals of the battery cell. With a large number of load resistances being available, more precise control can be performed on the charging operation of the individual cells during the battery charging operation.

In the above embodiments, resistors were connected across the terminals of the battery cells in order to control the charging of the battery cells. As those skilled in the art will appreciate, the resistors may be discreet components or they may be formed from semiconductor

devices, such as semiconductor resistors. Further still, semiconductor switches such as MOSFETS, bipolar transistors etc can be used as well as inductors.

In the above embodiment, the central battery monitoring system 3 monitored the cell voltages and cell temperatures for each of the cells in the battery and sent appropriate control signals to the microcontroller in each of the cell monitoring devices. As those skilled in the art will appreciate, in an alternative embodiment, each of the cell monitoring devices may determine its own control signals for controlling its current bypass circuitry 59. In this case, however, each of the cell monitoring devices CM_i would have to be more intelligent and they would have to know when the battery charger 10 is charging the industrial battery 1. Ideally, they would also know the battery charging characteristics of the battery cells.

In the above embodiment, messages were transmitted in one direction along the communication link 9. As those skilled in this art will appreciate, the communication

link 9 may be arranged to communicate messages in both directions between the cell monitoring devices to the central battery monitoring system.

In the above embodiment, a cell monitoring device was used to monitor each cell of the battery. In a cheaper implementation, each cell monitoring device CM_i could be used to monitor two or more series connected battery cells C_i.

In the embodiments described, the cells are connected in series. It is possible to connect the battery cells C_i in a series-parallel or ladder configuration. Figure 9 shows such an interconnection of battery cells, in which cell C_{ia} is connected in parallel with cell C_{ib} and the parallel combinations C_{ia} and C_{ib} are connected in series for i = 1 to n. In the configuration shown in Figure 9, a single cell monitoring device CM_i is provided for monitoring each of the battery cells and the communication link 9 connects CM_{ia} to CM_{ib} and CM_{ib} to CM_{i+1a} etc. Alternatively, a single cell monitoring device could be used to monitor each parallel combination of

battery cells C_{ia} and C_{ib}. Additionally, more than two battery cells can be connected in parallel.

In the above embodiments, the cell signalling devices are connected in series in a daisy chain configuration, with the position of each cell signalling device in the series communication link corresponding with the position of the cell or cells which are to power the cell signalling device in the series connection of battery cells. This is not essential. The cell signalling devices can be connected in any arbitrary series or series/parallel configuration relative to the series connection of battery cells. Further, radio frequency communication links may be provided between each cell signalling device and the central battery monitoring system.

In the above embodiments, each of the battery cells has a cell monitoring device which monitors the status of the associated battery cell. The provision of a cell monitoring device on each cell facilitates the control of the current bypass circuitry. However, it is not essential. In particular, the current bypass circuitry

for each cell may be directly connected, e.g. by separate wires, to the central battery monitoring system. Similarly, if a voltage sensor and a temperature sensor are provided on each cell, then these sensors may also be connected directly to the central battery monitoring system by separate wires. However, such an embodiment is not preferred because of the large number of wires and connectors that would be required.

In the above embodiments, each of the cell monitoring devices included the temperature sensor and the voltage sensors. As those skilled in the art will appreciate, separate temperature and/or voltage sensors may be provided for use with each cell monitoring device, in which case the cell monitoring devices would include terminals for receiving the signals from the respective sensors. However, this embodiment is not preferred since it requires separate electronic components which have to be connected together.

As those skilled in the art will appreciate, the cell monitoring devices may be provided integrally with the

battery cells. Alternatively, the cell monitoring devices may be provided separately from the battery cells in which case, they preferably have an appropriate mount for mounting the device on the cell. In this way the device can be used with existing battery cells.

The present invention is not limited by the exemplary embodiments described above, and various other modifications and embodiments will be apparent to those skilled in the art.

CLAIMS

1. A rechargeable battery system comprising:

a battery having a supply terminal and a reference terminal and a number of battery cells some of which are connected in series and connected between said reference terminal and said supply terminal;

a battery charger for charging said battery by applying a charging voltage across the reference terminal and the supply terminal of said battery;

means for sensing a measure of an existing charge of at least one of said battery cells of said battery;

means for comparing said sensed measure of the existing charge with a threshold value and for outputting a comparison result; and

means for selectively connecting a load across power terminals of said at least one battery cell in dependence upon the comparison result output by said comparing means, in order to control the charging of said at least one battery cell relative to the charging of the other battery cells during a charging operation of said battery.

2. A system according to claim 1, wherein said sensing means is operable to sense a measure of an existing

charge of a plurality of said battery cells of said battery; wherein said comparing means is operable to compare each sensed measure with a threshold value and to output a respective comparison result; and wherein said connecting means is operable to selectively connect a respective load across power terminals of each of said plurality of battery cells in dependence upon the respective comparison result output from said comparing means.

3. A system according to claim 2, wherein separate connecting means are provided for each of said plurality of battery cells.

4. A system according to claim 3, wherein said respective connecting means are located adjacent the corresponding battery cell.

5. A system according to any of the claims 2 to 4, wherein separate sensing means are provided for each of said plurality of battery cells.

6. A system according to claim 5, wherein the respective sensing means are located adjacent the corresponding battery cell.

7. A system according to any of claims 2 to 6, wherein a respective comparing means is provided for each of said plurality of battery cells.

8. A system according to claim 7, wherein the respective comparing means are located adjacent the corresponding battery cell.

9. A system according to any preceding claim, wherein said at least one battery cell includes a cell monitoring device which includes said sensing means, said connecting means and means for communicating with said comparing means.

10. A system according to claim 9, wherein said cell monitoring device, further includes said load.

11. A system according to claim 9 or 10, comprising a central battery monitoring system, including said comparing means, for communicating with said cell monitoring device and for controlling the initiation of a charging operation of said battery and for controlling the termination of said charging operation.

12. A system according to any of the claims 9 to 11, wherein said cell monitoring device comprises a microcontroller for processing the communications received by said communicating means and for controlling the operation of said connecting means.

13. A system according to any preceding claim, wherein said sensing means, comparing means and connecting means are operable to perform repeated operations during a charging operation of the battery.

14. A system according to any preceding claim, wherein said threshold value is determined in dependence upon the temperature of said at least one battery cell.

15. A system according to any preceding claim, wherein said threshold value is determined in dependence upon predefined battery charging characteristics of the battery.

16. A system according to any preceding claim, wherein said connecting means is operable to connect a variable load across said power terminals of said at least one battery cell.

17. A system according to any preceding claim, wherein said connecting means is operable to connect a load across said power terminals if said measure is above said threshold value.

18. A system according to claim 17, wherein said load is a resistive load having a resistance which causes a portion of the charging current to be diverted away from said at least one battery cell.

19. The system according to claim 17, wherein said load is a resistive load having a resistance which causes all of the charging current to pass through the load rather than passing through said at least one battery cell.

20. A system according to claim 19, wherein the resistive load has a resistance which causes current from the battery cell to be drawn through the load in addition to the charging current, thereby discharging said at least one battery cell during the charging operation.

21. A system according to any preceding claim, wherein said comparing means is operable to compare said sensed measure with a plurality of threshold values and wherein

said connecting means is operable to connect, across said power-terminals, a load whose value depends upon the result of the comparisons of the said sensed measure with said plurality of threshold values.

22. A system according to any preceding claim, wherein said charging voltage is constant.

23. A system according to any preceding claim, wherein said load is a resistive load comprising at least one of: a resistor, a switch and an inductor.

24. A battery cell monitoring device comprising:

means for receiving a measure of an existing charge of the battery cell to be monitored;

means for communicating said measure to a remote monitoring system;

means for receiving a control signal from said remote monitoring system;

a load connectable across power terminals of said battery cell; and

means for selectively connecting said load across said power terminals of said battery cell in dependence upon the control signal received from said remote monitoring system.

25. A battery cell monitoring device comprising:

means for receiving a measure of an existing charge of the battery cell to be monitored;

means for comparing the measure with a threshold value and for outputting a comparison result; and

means for selectively connecting a load across said power terminals of the battery cell in dependence upon the comparison result output by said comparing means.

26. A device according to claim 24, further comprising of a microcontroller which is operable to control communications with said remote monitoring device and to control the operation of said connecting means.

27. A device according to any of claims 24 to 26, further comprising a sensor for sensing said measure of the existing charge of the battery cell.

28. A device according to any of claims 24 to 27, wherein said measure of the existing charge is the voltage of the battery cell.

29. A device according to any of claims 24 to 28, comprising means for receiving power from the battery cell it is to monitor.

30. A device according to any of claims 24 to 29, further comprising means for mounting the device on the battery cell to be monitored.

31. A device according to any of claims 24 to 30, comprising a plurality of loads, each connectable across said power terminals of said battery cell, and wherein said connecting means is operable to selectively one or more of said loads across said power terminals.

32. A battery monitoring kit comprising a plurality of battery cell monitoring devices according to any of the claims 24 to 31.

33. A storage medium storing processor implementable instructions for controlling a programmable processor device to become configured as a device according to any of claims 24 to 32 when said instructions are loaded into said programmable processor.

34. Processor implementable instructions product for controlling a programmable processor device to become configured as a device according to any of claims 24 to 32 when said instructions product is run on said programmable processor.

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Application No:	GB 0104416.3	**Examiner:**	Rowland Hunt
Claims searched:	1-23, 25-34	**Date of search:**	6 September 2001

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H2H (HBCD, HBCG, HBCH)

Int Cl (Ed.7): H01M 10/44; H02J 7/00, 7/04, 7/08, 7/10

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	US 5880575	(SANYO) see particularly fig. 1	1-4, 9-13, 17-19, 22, 23, 25, 27, 28, 30, 33, 34
X	US 5773959	(LOCKHEED MARTIN) see particularly fig. 4	1-13, 17-19, 22, 23, 25, 27, 28, 33, 34
X	US 5557189	(SONY) see particularly fig. 6	1-6, 9-13, 16-19, 23, 25, 27, 28

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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